

## Abstract

Estimation of the Radar Cross Section of large inhomogeneous scattering objects such as composite aircrafts, ships and biological bodies at high frequencies has posed large computational challenge. The detection of scattering from wake vortex leading to detection and possible identification of low observable aircrafts also demand the development of computationally efficient and rigorous numerical techniques. Amongst the various methods deployed in Computational Electromagnetics, the Method of Moments predicts the electromagnetic characteristics accurately. Method of Moments is a rigorous method, combined with an array of modeling techniques such as triangular patch, cubical cell and tetrahedral modeling. Method of Moments has become an accurate technique for solving electromagnetic problems from complex shaped homogeneous and inhomogeneous objects. One of the drawbacks of Method of Moments is the fact that it results into a dense matrix, the inversion of which is a computationally complex both in terms of physical memory and compute power. This has been the prime reason for the Method of Moments hitherto remaining as a low frequency method. With recent advances in supercomputing, it is possible to extend the range of Method of Moments for Radar Cross Section computation of aircraft like structures and radiation characteristic of antennas mounted on complex shaped bodies at realistic frequencies of practical interest. This thesis is a contribution in this direction.

The main focus of this thesis is development of parallel Method of Moments solvers, applied to solve real world electromagnetic wave scattering and radiation problems from inhomogeneous objects. While the methods developed in this thesis are applicable to a variety of problems in Computational Electromagnetics as shown by illustrative examples, in specific, it has been applied to compute the Radar Cross Section enhancement due to acoustic disturbances and flow inhomogeneities from the wake vortex of an aircraft, thus exploring the possibility of detecting stealth aircraft. Illustrative examples also include the analysis of antenna mounted on an aircraft.

In this thesis, first the RWG basis functions have been used in Method of Moments procedure, for solving scattering problems from complex conducting structures such as aircraft and antenna(s) mounted on airborne vehicles, of electrically large size of about  $45\lambda$  and 0.76 million unknowns.

Next, the solver using SWG basis functions with tetrahedral and pulse basis functions with cubical modeling have been developed to solve scattering from 3D inhomogeneous bodies. The developed codes are validated by computing the Radar Cross Section of spherical homogeneous and inhomogeneous layered scatterers, lossy dielectric cylinder with region wise inhomogeneity and high contrast dielectric objects.

Aerodynamic flow solver ANSYS FLUENT, based on Finite Volume Method is used to solve inviscid compressible flow problem around the aircraft. The gradients of pressure/density are converted to dielectric constant variation in the wake region by using empirical relation and interpolation techniques. Then the Radar Cross Section is computed from the flow inhomogeneities in the vicinity of a model aircraft and beyond (wake zone) using the developed parallel Volume Surface Integral Equation using Method of Moments and investigated more rigorously. Radar Cross Section enhancement is demonstrated in the presence of the flow inhomogeneities and detectability is discussed. The Bragg scattering that occurs when electromagnetic and acoustic waves interact is also discussed and the results are interpreted in this light. The possibility of using the scattering from wake vortex to detect low visible aircraft is discussed.

This thesis also explores the possibility of observing the Bragg scattering phenomenon from the acoustic disturbances, caused by the wake vortex. The latter sets the direction for use of radars for target identification and beyond target detection.

The codes are parallelized using the ScaLAPACK and BiCG iterative method on shared and distributed memory machines, and tested on variety of High Performance Computing platforms such as Blue Gene/L (22.4TF), Tyrone cluster, CSIR-4PI HP Proliant 3000 BL460c (360TF) and CRAY XC40 machines. The parallelization speedup and efficiency of all the codes has also been shown.